California Air Resources Board

Co-benefit Assessment Methodology
Heart and Lung Health

California Climate Investments
Greenhouse Gas Reduction Fund

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Section A. Introduction

The goal of California Climate Investments is to reduce greenhouse gas (GHG) emissions and further the objectives of the California Global Warming Solutions Act of 2006, Assembly Bill (AB) 32. The California Air Resources Board (CARB) is responsible for providing guidance on reporting and quantification methods for all State agencies that receive appropriations from the Greenhouse Gas Reduction Fund (GGRF). Guidance includes developing methodologies for estimating GHG emission reductions and other economic, environmental, and public health benefits of projects, referred to as "co-benefits."

CARB staff developed this Heart and Lung Health Co-benefit Assessment Methodology (methodology) to estimate heart and lung health impacts for relevant California Climate Investments programs. Most Co-benefit Assessment Methodologies are intended for use by administering agencies, project applicants, and/or funding recipients to estimate the outcomes of individual California Climate Investments projects. For this methodology, however, CARB will apply the methods described in this document at a larger scale across all California Climate Investments. In addition to this methodology, general guidance on assessing California Climate Investments co-benefits is available in CARB's Funding Guidelines for Agencies Administering California Climate Investments (Funding Guidelines) available at www.arb.ca.gov/cci-fundingguidelines.

Heart and Lung Health Co-benefit Description

Heart and lung health co-benefit refers to the expected change in the incidence of premature cardiopulmonary mortality, hospitalizations for cardiovascular and respiratory illness, and emergency room visits for respiratory illness and asthma as a result of California Climate Investments. These health impacts occur because California Climate Investments projects change the emissions of particulate matter ($PM_{2.5}$), diesel particulate matter (diesel PM), and nitrogen oxides (NO_X).

Individual California Climate Investments projects may cause reductions or increases in air pollutants but, overall, it is expected that the suite of funded projects will reduce air pollutant emissions and result in a positive heart and lung health co-benefit. These co-benefits may accrue directly (as a central objective of the project) or indirectly (as a consequence of project activities).

A ***positive*** heart and lung health co-benefit results when California Climate Investments projects within an air basin reduce emissions of $PM_{2.5}$, diesel PM, and NO_X.

A ***negative*** heart and lung health co-benefit results when California Climate Investments projects within an air basin increase emissions of $PM_{2.5}$, diesel PM, and NO_X.

Heart and Lung Health Co-benefit Projects

This Co-benefit Assessment Methodology will apply to all California Climate Investments projects for which a change in $PM_{2.5}$, diesel PM, and/or NO_X is estimated using CARB GHG Quantification Methodologies and Benefit Calculator Tools.

California Climate Investments that result in a change in air pollutant emissions and heart and lung health co-benefits include projects in the transportation, energy, natural and working lands, and waste sectors.

Methodology Development

CARB developed this Co-benefit Assessment Methodology, consistent with the guiding principles of California Climate Investments. The methodology is developed to:

- Apply to the project types proposed for funding;
- Provide uniform methods that can be applied statewide and are accessible by all applicants and funding recipients;
- Use existing and proven tools or methods, where available;
- Include the expected period of time for when co-benefits will be achieved; and
- Identify the appropriate data needed to calculate co-benefits.

In April 2018, CARB released a Draft Asthma/Respiratory Disease Incidence Co-benefit Assessment Methodology, developed by the Center for Resource Efficient Communities at the University of California, Berkeley (UC Berkeley). UC Berkeley assessed peer-reviewed literature and consulted with experts, as needed, to identify:

- The direction and magnitude of the co-benefit;
- Project types to which the co-benefit is relevant;
- The limitations of existing empirical literature;
- Existing assessment methods and tools; and
- Knowledge gaps and other issues to consider in developing co-benefit assessment methods.

This work is summarized in a literature review on this co-benefit, which can be found at: www.arb.ca.gov/cci-cobenefits. UC Berkeley also considered ease of use, specifically the availability of project-level inputs from users for the applicable California Climate Investments programs.

CARB staff periodically review each methodology to evaluate its effectiveness and update methodologies to make them more robust, user-friendly, and appropriate to the projects being quantified. After posting the Draft Asthma/Respiratory Disease Incidence Co-benefit Assessment Methodology and receiving public comments, CARB decided to revisit the approach and scope of the method. CARB released a Draft Heart and Lung Health Co-benefit Assessment Methodology for public comment in October 2018 prior to release of this Final Heart and Lung Health Co-benefit Assessment Methodology.

Program Assistance

For assistance with this Co-benefit Assessment Methodology, send questions to: GGRFProgram@arb.ca.gov. For more information on CARB's efforts to support implementation of California Climate Investments, see: www.arb.ca.gov/auctionproceeds.

Section B. Co-benefit Assessment Methods

Introduction

While funding recipients and/or administering agencies typically carry out project-level assessments of co-benefits from California Climate Investments, projected changes in health impacts from air pollutant emissions are not large enough to quantify at the project level. Therefore, CARB will use an existing, reliable methodology for calculating health impacts to estimate the combined heart and lung health co-benefits of all California Climate Investments. This section describes how CARB will estimate the Heart and Lung Health co-benefit.

Overall, the methods for assessing the heart and lung health is quantitative, using the estimated changes in $PM_{2.5}$, diesel PM, and NO_X during the project quantification period[1] compared to a no-project scenario. CARB uses a U.S. EPA methodology to estimate the health impacts associated with total $PM_{2.5}$, from which impacts associated with diesel particulate matter (diesel PM) and nitrogen oxides (NO_X) are derived.[2] The level of co-benefit for heart and lung health impacts is determined using a health impact function that incorporates four main elements: emissions reductions of diesel PM and NO_X, the population affected, relevant mortality and morbidity data, and concentration-response functions.

Methods of Analysis

The basis of the methodology is the approximately linear relationship that holds between estimated changes in health outcomes and emissions in a given air basin.

Emissions reductions from California Climate Investments projects may come from a variety of source types, which include on-road mobile sources, off-road mobile sources, and stationary sources. Sources at ground level in densely populated areas, such as motor vehicles in cities, will have a greater impact on the exposed population than sources emitted far above the ground or in sparsely populated areas. Therefore, staff begin by multiplying emissions from off-road and stationary sources by a weighting factor. The weighting factor is calculated using intake fractions (IF), which are defined as the fraction of a source's emissions that are inhaled by the population. Specifically, the weighting factor is the ratio of the IF for a given off-road or stationary source to the IF for on-road motor vehicles.

The number of avoided incidents (i.e., premature cardiopulmonary mortality, hospitalizations for cardiovascular and respiratory illness, and emergency room visits for respiratory illness and asthma) associated with reductions in diesel PM and NO_X is estimated by multiplying those emission reductions by a scaling factor, the incidence-per-ton (IPT) factor. IPT factors are calculated separately for diesel PM and NO_X within each air basin by dividing the number of incidents associated with exposure to diesel

[1] The project quantification period varies for the different programs and is defined in each of CARB's GHG Quantification Methodologies and Benefit Calculator Tools.

[2] Fann et al. 2009. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2770129/

PM and ammonium nitrate—using NO_X as a surrogate—by the emissions (tons per year) of diesel PM and NO_X, respectively, in that air basin.[3]

In addition to primary $PM_{2.5}$, NO_X is a secondary pollutant and precursor to the formation of ammonium nitrate PM. For secondary PM, CARB calculates the health impacts resulting from the three-year average exposure to ammonium nitrate PM and then associate the impacts with the basin-specific NO_X emissions.

Calculation of the change in incidents associated with changes in $PM_{2.5}$ exposure requires population data, baseline incidence rates, the change in concentration of $PM_{2.5}$,[4] and concentration-response functions (CRF):

- Population is estimated by taking 2010 Census data for total population by age bracket[5] and projecting to future years using total county population projections from the California Department of Finance.[6]

- Age-specific baseline incidence rates are taken from the Centers for Disease Control and Prevention Wonder online databases. In the analysis of California Climate Investments, CARB will use reference air quality data and baseline incidence rates for the years 2014-2016.

- The change in concentration of $PM_{2.5}$ will be determined using $PM_{2.5}$ emission reductions reported for California Climate Investments projects. This analysis interprets changes in emissions as proportional to changes in ambient concentrations, allowing a straightforward analysis of the effects of projected emissions reductions attributed to California Climate Investments.[7] Concentrations of diesel PM are indirectly estimated from NO_X concentrations using an established conversion factor.[8]

- Concentration-response functions describe the relationship between a given health endpoint and concentration of the pollutant of interest. For this co-benefit assessment, CARB will apply a CRF for premature death from Krewski et al.,[9] CRFs for hospital admissions from Bell et al.,[10] and a CRF for

[3] The IPT factors used for primary $PM_{2.5}$ in this assessment were originally developed for use with diesel PM emissions, but are also applied to PM from light-duty vehicles. This assumes that emission patterns, dispersion mechanisms, and loss mechanisms of primary PM from all on-road vehicular sources are expected to be similar. That is, a ton of PM emitted from on-road non-diesel vehicles is expected to result in the same $PM_{2.5}$ exposure and health effects as a ton of $PM_{2.5}$ emitted from on-road diesel trucks.
[4] CARB 2010. https://www.arb.ca.gov/regact/2010/truckbus10/correctedappj.pdf
[5] CARB will use 5-year age brackets from ages 30 to 80, and an 85+ age bracket. Calculations are performed separately for each age bracket by 2010 US Census tract, then aggregated to totals by air basin.
[6] This accounts for overall population growth in a county but does not reflect shifts in the spatial distribution of the population such as new housing developments built on previously undeveloped land.
[7] CARB 2010. https://www.arb.ca.gov/regact/2010/truckbus10/correctedappj.pdf
[8] Propper et al. 2015. https://www.ncbi.nlm.nih.gov/pubmed/26340590
[9] Krewski et al. 2009. https://ephtracking.cdc.gov/docs/RR140-Krewski.pdf
[10] Bell et al. 2008. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2732959/

emergency room visits by Ito et al.[11] These references are selected in accordance with recent U.S. EPA practice. The concentration-response functions fit specific population parameters:

1) Premature mortality incidence applies to the population of adults who are 30 years and older,[12]
2) Hospitalization incidence applies to the population 65 years and older,[13] and
3) The incidence of emergency room visits applies to the population between 0 and 99 years of age.[14]

- For premature death, we assume that each CRF is approximately linear down to a concentration of 5.8 µg/m, the lowest concentration analyzed in Krewski et al.[15] and reductions in $PM_{2.5}$ to below that level are not quantified.

Heart & Lung Health Results

The Research Division at CARB will perform the analysis of the overall heart and lung health co-benefits associated with changes in emissions from California Climate Investments projects, by air basin. The results will include the cumulative statewide number of avoided incidents for projected years, showing the estimated reductions in each incident (i.e., premature cardiopulmonary mortality, hospitalizations for cardiovascular and respiratory illness, and emergency room visits for respiratory illness and asthma) resulting from California Climate Investments. If cumulative statewide impacts are less than ten avoided incidents, the report will rely on qualitative analysis.

It is important to note that there is uncertainty inherent in these mortality and morbidity estimates. A number of sources may contribute to uncertainty ranges, which will be expressed using a 95% confidence interval in the final data. The ranges included in the data will account for uncertainty of the relative risk, which determines how changes in air quality translate into changes in mortality and morbidity rates. Other factors, such as the uncertainty associated with spatially interpolating air quality data, are not included in the heart and lung health analysis, yet also contribute to the variability in estimates. It is likely that uncertainty ranges in mortality and morbidity estimates that will be included in the report understate the true uncertainty.

[11] Ito et al. 2007. http://www.nature.com/jes/journal/v17/n2s/full/7500627a.html
[12] Krewski et al. 2009. https://ephtracking.cdc.gov/docs/RR140-Krewski.pdf
[13] Bell et al. 2008. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2732959/
[14] Ito et al. 2007. http://www.nature.com/jes/journal/v17/n2s/full/7500627a.html
[15] Krewski et al. 2009. https://ephtracking.cdc.gov/docs/RR140-Krewski.pdf

Section C. Data Requirements

This section describes the data requirements for the Heart and Lung Health Co-benefit Assessment Methodology that need to be provided to the Research Division. The project-level data that CARB will need to estimate the heart and lung health impacts include the following:

- **Change in $PM_{2.5}$, Diesel PM, and NO_X Emissions:** The emission reductions or increases provided as an output from a CARB Benefit Calculator Tool.
- **Project Location:** Air basin where emission reductions or increases are expected.

  CARB staff will annualize the project-level emissions data over the project quantification period, categorize by source type (i.e., on-road mobile sources, off-road mobile sources, and stationary sources), aggregate by air basin and provide to the Research Division in tons of each pollutant reduced per year through 2060.

> When inputs required to estimate heart and lung health are inputs to, or outputs from, a CARB GHG Quantification Methodology or Benefit Calculator Tool (e.g., air pollutant emissions), the values used in estimation of GHGs and co-benefits must be identical.

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